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equal in length, commonly shorter than the main stem, the ultimate divisions less than one-half the length of a single zoëid, each division supporting a single animal-cule; entire pedicel stout, longitudinally striate; contracted zoëid obovate or sub-pyriform, the frontal border projecting in snout-like manner, and the anterior body-half thrown into prominent longitudinal plications, the posterior body-half into several annulations. Length of body $\frac{1}{4}\frac{1}{17}$ (0.0024) inch; height of main stem $\frac{1}{3}\frac{1}{3}\frac{1}{4}$ (0.0030); of the entire colony $\frac{1}{11}\frac{1}{2}$ (0.0090) inch. Habitat: Attached to *Cladophora glomerata* on the shore of Luna island in the rapid water of the Niagara river.

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NOTES ON THE PHYSICAL GEOGRAPHY OF THE AMAZONS VALLEY.

BY HERBERT H. SMITH.

MOST of our common maps indicate a triple division of the Amazons, the Peruvian portion being called Marañon, the Middle Amazons, Solimoens, while all below the junction of the Rio Negro is distinguished as the Lower Amazons. Geographers have treated this division as one of custom and convenience only, and so far as the Peruvian portion, or Marañon, is concerned, they are right; its distinction from the Solimoens is merely nominal, Brazilians and Peruvians speaking of both portions as the Upper Amazons. But this *Alto Amazonas* is constantly and clearly distinguished from the lower or main river. "The Amazons," say the river pilots, "is formed by the junction of the Solimoens and the Rio Negro; the Solimoens is called Upper Amazons because it is longer and has more important settlements on its banks, but it is really a branch like the Negro. Indeed, at the junction it is the Solimoens which forms an angle, while the Negro is directly in a line with the Lower Amazons, so that it appears to be the main river." This idea is universal among the river people, and it has led to many important results. The "Amazons" and "Solimoens" are well recognized in commercial affairs, and they have even formed the basis of a political division, the limits of the provinces of Pará and Alto Amazonas corresponding pretty nearly with those of the Lower and Upper Amazons.

The division is, in fact, much more significant than geographers have supposed. Whatever may have led to the distinction of names, there is a real and well-marked physical division, not only of the river itself, but of the country and its fauna and flora. Mr. Bates is, I believe, the only traveler who has clearly indicated

some of the differences between the two regions. Following him in part we may thus divide them :

1. The Upper Amazons region, to the base of the Andes and for hundreds of miles on both sides of the river, is a perfectly level expanse, nowhere raised more than a hundred and fifty feet above the river and generally only just out of reach of the highest floods. The Lower Amazons, on the contrary, passes through a comparatively high country, with table-lands several hundred feet above the river and many abrupt hills or even mountains. These elevations increase towards the north and south until they join the great table-lands of Guiana and Brazil.

2. As a consequence the great tributaries of the Upper Amazons—notably the Purús, Juruá and Içá—present a perfectly open navigation almost to their sources ; but those of the Lower Amazons are obstructed by rapids and falls where the water flows down from the highlands. A secondary consequence is that the Upper Amazonian branches are very crooked, while those of the Lower Amazons are comparatively straight.

3. The soil of the Upper Amazons is either a rich ferruginous clay or vegetable mold which, according to Bates, often attains a thickness of twenty or thirty feet ; stones are hardly ever met with. On the Lower Amazons the soil is nearly always sandy, and mold forms only in favored localities, such as swamps and river-banks.

4. On the Upper Amazons the trade-wind is never felt, and the air is always moist and warm ; rains are very frequent, especially near the Andes, and the dry season is only marked by the comparative lightness of the daily showers. On the Lower Amazons the trade-winds blow freely during a great part of the year, and there is a well-marked dry season ; in some districts the rains cease almost entirely for weeks together. Probably the average temperature is somewhat lower near the Atlantic than on the Upper Amazons.

5. The great forest of the Upper Amazons, so far as we know, is unbroken except by the rivers, and it has a width of a thousand miles or more from north to south. The forest belt of the Lower Amazons is hardly half so wide, and it is interrupted in many places by *campos* or open lands, either grassy or stony plains, without trees, or sandy tracks with a thin semi-forest growth like that of Central Brazil.

6. The alluvial flood-plains of the Upper Amazons are far more extensive than those of the lower river, probably attaining in some places a width of at least one hundred miles. They are covered everywhere with heavy forest which, during a large portion or the whole of the year are flooded, so that canoes can pass freely underneath the branches. On the Lower Amazons the alluvial belt varies in width from fifteen to forty miles, and it is occupied, in great part, by open meadows which are only flooded during the rainy season.

7. The fauna and flora of the Upper Amazons are exceedingly rich in genera and species, and they are almost entirely composed of forms which are fitted only for a forest life. On the Lower Amazons such forms are mingled with others which belong to the open lands, or which are not essentially sylvan; in general the species are less numerous than on the Upper Amazons, and many of them are distinct, but allied or "representative" forms. Those species which are common to the two regions are frequently larger and of more rapid growth on the Upper Amazons.

As may be supposed the two regions fade into each other, but something like a definite boundary between them is formed by the Rio Negro on the north and the Madeira on the south side of the Amazons. These, the former with its broad expanse of water, the latter with its immense flood-plain, are almost impassable barriers to the migration of species. They, together with the main river, divide the whole Amazons valley into four parts, each of which is characterized by a pretty large number of animals and plants. The other great tributaries may limit lesser groups of species, and the great flood-plain has a perfectly distinct assemblage of animals and plants which, in their turn, differ essentially on the Upper and Lower Amazons.

Let us now, for the moment, leave the Solimoens and confine our attention to the region east of the Rio Negro and Madeira. The valley of the Lower Amazons is limited on the north by the mountain range which separates British and Dutch Guiana from Brazil. Most of these mountains are table-topped, and they are clearly remains of a great elevated plain. The region, two or three hundred miles wide, which separates them from the Amazons, is very imperfectly known, but it appears to be almost entirely occupied by a less elevated plain, edges or spurs of which

are seen near the river in the table-topped hills of Almeyrim and Velha Pobre, each more than 1500 feet high. This plain may be regarded as a great terrace, abutting abruptly against the high peaks of the Guiana chain, and cut down as sharply near the Amazons to a second terrace which forms a low region between the table-topped hills and the river flood-plain. Sometimes an intermediate terrace may be distinguished, as at Monte Alegre and Prainha; outlying and much denuded portions of the upper terrace are seen in the rugged hills of Ereré and Tajury, west and north of Monte Alegre.

The southern side of the valley, from the Madeira eastward, seems to be everywhere a low table-land, which rises gradually or by terraces to the elevated plains of Central Brazil. Near the Amazons and its tributaries it is abruptly cut down, forming bluffs three or four hundred feet high. A line of these bluffs extends, with slight interruptions, from the Tocantins almost to the Madeira. Generally the bluffs form the southern edge of the Amazonian flood-plain, but in some places, as near Santarem, they are separated from it by strips of low land answering to the lower terrace on the northern side. The bluffs themselves may correspond to the intermediate terrace of Monte Alegre and Prainha.

Between these northern and southern terraces, crossing the country from W.S.W. to E.N.E., is a low, flat, perfectly level expanse, very irregular in outline and varying in width from fifteen to forty miles; at the Atlantic end only it spreads out like a funnel, occupying perhaps a hundred miles of coast. The yellow Amazons winds through this flood-plain, rarely touching the borders, now pouring through the narrow pass at Obidos, now expanded into sea-like reaches, again broken into two or three portions, separated by great islands. Everywhere the alluvial land is dotted with shallow lakes and seamed with channels—goodly rivers which hardly appear on the maps. Constant changes are taking place in this network; new islands and shallows are formed almost every year, and old ones are altered or washed away. I know of one island, three miles long, which disappeared completely in less than ten years; the river steamboats now pass directly over its site.

On the Lower Amazons the islands and river-borders of the flood-plain are called *varzeas*, though properly the term is applied

only to those portions which are above water during more than half the year; lower and perennially wet tracts are known as *ygapós*.¹ In contradistinction, all dry land which is out of reach of the annual floods is called *terre-firme*. Islands of high land (*ilhas de terra-firme*) are frequently seen in the midst of the *varzeas* and along the irregular borders of the flood-plain it often happens that the *varzea* and *terre-firme* are mingled in the most complicated manner; such places would be puzzling enough to the student were it not that the alluvial land can be at once distinguished by its vegetation. Frequently the *varzea* or *ygapó* forest is continuous with that of the *terre-firme*, but the trees are always of distinct species, and no experienced woodsman would think of confounding them.

On the southern side of the mouth of the Amazons, separating it from the Tocantins and Pará, is a great lozenge-shaped island called Marajó. At its south-western end it is separated from the mainland by a network of narrow channels connecting the Amazons with the Tocantins. The tides ebb and flow in these channels but the south-westerly current predominates, so that a portion of Amazonian water reaches the Tocantins. The channels are cut through a wide stretch of alluvial land which is directly continuous with the flood-plain of the Amazons. Marajó itself is almost entirely composed of or covered with alluvial deposits. The eastern and northern parts of the island are occupied by *varzea* meadows, while the southern and western portions are almost continuous swamps, noted for their rubber trees and for their deadly fevers. The whole island abounds in shallow lakes, and it is cut up by hundreds of small creeks and channels, the haunts of alligators and serpents. Only along the eastern and southern edges there are some narrow strips of *terre-firme*, true rocky land raised well above the highest floods. The first settlers took advantage of these little dry spots, building their houses on them and sheltering their cattle there when the meadows were overflowed. Breves and other villages owe their situations to these *torroes*.

From the highlands of Guiana a number of rivers flow down, with many rapids and falls, to the Amazons. None of these streams have been explored to their sources, and most of them are known only near their mouths, where they flow across the

¹ In Tupy, a wet land or swamp.

region which I have called a lower terrace. As soon as they enter this region the rapids cease, and immense flood-plains spread out on both sides. Besides the fact that these flood-plains are out of all proportion to the rivers, they are remarkable for the extreme irregularity of their borders. Every little stream which enters the main affluent passes through a flood-plain of its own, often five or six miles broad, though the stream itself may be hardly as many feet across. Crooked bays of *varzea* extend far into the mainland; numberless islands of *terre-firme* are scattered over the flood-plain; and the most conscientious map-maker who attempts to unravel this tangle is likely to give up in despair. The irregularity generally increases toward the Amazons, where the alluvial land of the tributaries spread out broadly until it is lost in the Amazon flood-plain.

Three great tributaries—the Tapajós, Xingú and Tocantins—flow down over the southern table-land from the center of South America. Geographically it should be said, the Tocantins cannot be regarded as a tributary of the Amazons; its mouth, called the Pará river, receives a portion of Amazonian water, but it opens into the Atlantic and is separated from the main mouth of the Amazons by Marajó. Physically the three rivers resemble each other closely. They are all clear-water streams, flowing down, with many rapids, to a point about 150 miles from their mouths, where the rapids cease, and the rivers gradually expand into quiet lakes. The lakes are bordered by bluffs, edges of the table-land and continuous with those which border the southern side of the Amazonian flood-plain. In their lower portion these lakes are from seven to ten miles wide and very deep; they have hardly any current, but rise and fall with the tides as regularly as the sea. At their northern ends they are suddenly contracted by the Amazonian flood-plain, and here they receive Amazonian water through narrow channels or *furos*. The *furos*, where they open into the lakes, are still bringing in Amazonian sediment, and they have thus pushed their mouths far into the clear water. The Tapajós and Xingú finally reach the Amazons through embouchures less than half a mile broad—about the average width of these rivers near their lower falls.

Some smaller rivers which enter the Amazons from the south have more or less muddy waters, and these have filled up their valleys with sediment. The flood-plains thus formed are bordered

by bluffs precisely like those along the Lower Tapajós and Xingú. It is evident, then, that these muddy rivers, in their lower courses, were once expanded into lake-like reaches, similar to those of the clear-water tributaries.

If we now return to the northern side of the Amazons we shall find at least one clear-water tributary, the Trombetas, which is lake-like along its lower courses. But as the river here passes through low *terre-firme*, the bluffs are wanting; the borders are extremely irregular, and numerous small lakes open into the main one on either side; islands or peninsulas of low, rocky land separate these lakes from the river, and smaller islands are cut off in the lakes or in the river itself.¹ In fact the whole corresponds precisely to the irregular flood-plains of the other northern tributaries. The latter, being muddy, have filled up the lakes and channels with sediment, and they now wind about in broad alluvial tracts, the borders of which seem to be inextricably mingled with the *terre-firme*.

I believe it can be shown that all the main tributaries of the Lower Amazons are, or have been, lake-like in their lower courses. The question then arises: Were these lakes produced by a damming back of the tributaries by Amazonian silt, so that they filled up their valleys? I think not. No doubt the alluvial land, closing the mouths of the lakes, has tended to raise their waters; but the flood-plain of the Lower Amazons is everywhere so near the level of the sea that this uplift cannot have been very great. The tides, which are felt on the main Amazons as far as Obidos, are very apparent on the Lower Xingú and Tapajós; Bates noticed them on a secondary tributary of the latter river nearly six hundred miles from the ocean. It is well, also, to note the similarity of the Tapajós and Xingú to the Tocantins, which opens broadly into the sea and cannot owe its lake-like lower course to any damming back of the waters.

Having reached this point it requires but little imagination to apply the same reasoning to the Amazons itself; to look upon the flood-plains as a filled-up sea or great bay, with many branches, which now form the flood-plains or tidal-lakes of the tributaries. Let us go back in imagination to the period before this sea was filled up and map out the Amazonian system as it then was.

Stretching eight hundred miles west-south-westward from the

I owe these notes on the topography of the Trombetas to Professor O. A. Derby.

Atlantic, a narrow estuary bay or inland sea divided the northern part of the South American continent. The water in the eastern portion was clear and salt; heavy tides swept up the long sand-beaches and dashed against the cliffs of clay and conglomerate. In general the channel was clear, but here and there little rocky islands added to the picturesque beauty of the shores. On the northern side a number of blue mountains could be seen; spurs and outlyers of the table-land which stretched down from the Guiana chain. To the south a line of bluffs fronted the water, the northern edge of another great table-land. The Tapajós, Xingú, Trombetas and many smaller rivers flowed into the Amazonian sea through long branch estuaries or tidal bays. Some of these streams were muddy and tended to fill up their mouths; others preserved clear, deep channels.

Just at its mouth, on the southern side, the great estuary met a lesser one, now the Lower Tocantins, and its outlet, the Pará. The two bays were partly separated by a string of low sandy islands and reefs, like those now fronting the sounds along the south-eastern coast of the United States. These reefs now form the *torrões* along the southern and eastern side of Marajó.

In the Amazonian bay the greatest extent of brackish or fresh water was towards the western end, where the water was shallow and much obstructed by islands. Islands and shallows owed their existence to, and were yearly being built up by, the Solimoens and Madeira, which here poured in their floods of muddy water. The mouths of these rivers formed two branches at the head of the bay; a third branch marked the outlet of the Negro, which, as it brought down little sediment, preserved a wide and clean channel.

Then, as now, the trade-wind blew in freely from the Atlantic, and the climate was equable and moist. The plants and animals of the shores were probably similar to those which now inhabit the highland, but the great estuary formed an impassable barrier to many species, and the Guiana fauna and flora were more sharply divided from those of Brazil. The estuary itself was inhabited principally by marine forms of fishes, Crustacea and Mollusca; only at the western end, where the larger rivers emptied in, brackish-water forms prevailed.

Gradually the alluvial land at the head of the bay extended eastward, filling up the estuary with islands. As this eastward

movement went on, the branch estuaries were blocked up at their mouths by the islands which formed in front of them. Where the branch received a muddy tributary it also was filled up; but the clear-water tributaries, like the Tapajós, Xingú and Tombetas, brought down no sediment, and their estuaries, closed at the mouths, assumed the form of lakes.

In this way the whole of the Amazonian flood-plain has been built up. Passing now a step farther back it is easy to see that the flood-plains of the Solimóens and Madeira were formed in the same way. But the vast extent of this alluvial land on the Upper Amazons seems to indicate a widening of the great bay at its upper end; a kind of inland sea connected with the ocean towards the east by a comparatively narrow strait.¹ This sea, at the period of which I am speaking, had no connection with the Orinoco valley, for the Amazonian flood-plain is now separated from that river by rocky *terre-firme*, indicated by the falls of the Orinoco and Negro. Several large rivers, flowing down from the Andes, emptied into the sea near its western end, and eventually transformed it into a river by filling its bed with sediment. These Andean torrents still exist as the Huallaga, Ucayale, Napo, Tigre and extreme Upper Amazons.

Such a branched estuary bay as I have described could only have been formed by the subsidence of land over a great area, and the encroachment of the sea on the valleys of some former Amazons and its tributaries. This subsidence must have taken place subsequently to the deposition of the clays and sandstones which form much of the *terre-firme* along the Lower Amazons. For the very tributaries on which the above arguments have been based flow through valleys which they have cut in the clays and sandstones themselves. It appears probable, also, that the period of subsidence was anterior to the formation of the *Tabatinga* clays on the Upper Amazons.

For the sake of clearness I have described the silting-up of the valley as occurring during a period of repose subsequent to the subsidence. But it is quite possible that the subsidence and filling up were, in part, contemporaneous. The Upper Amazonian sea may have had its outlet through a Lower Amazonian river

¹It may be, however, that this widened flood-plain is due to the extreme shallowness of the valley of the upper river; the Amazons, dammed back somewhat by the accumulations below, would tend to spread out on either side and build up its own bed.

which, by the sinking of the land, was changed to an estuary while the sea was being filled with sediment. These questions must be settled by a more careful study of the Upper Amazons and its tributaries and especially of the Madeira and Negro. But whatever the changes may have been it is certain that the Amazonian river system is much older than the period of subsidence of which I have spoken. The slow pulsations of the earth have sent many throbs to this equatorial region; centuries of subsidence have been followed by centuries of upheaval, and these again by depression; river has become sea and sea has passed into river and estuary again and again since first the rains and springs united to form an infant Amazons. We have some glimpses of this older history, but as yet geological exploration on the Amazons is too new to give us any very clear sequence of events.

It appears certain that the immense low plain of the Upper Amazons was occupied by a Tertiary sea, older and much larger than the one which has been described above. Tertiary marine shells have been found at several points on the Marañon and Solimões, and the *Tabatinga* clays which contain these shells extend far up the Japurá and Purús. The upheaval which placed these clays beyond reach of the river waters may have taken place long previous to the estuary depression, and many changes may have intervened. It appears probable that this Tertiary sea opened into the Atlantic through what is now the valley of the Orinoco, and that the Cassiquiare, which at present unites the two great river-systems, may correspond to one side of the strait or channel. It has been supposed that the sea had two outlets, one by the Orinoco valley and the other by that of the Lower Amazons, and that the Guiana highland formed a great island between them. Of this I think there is no sufficient proof. On the Lower Amazons the bluffs between the Tapajós and Tocantins and the table-topped hills of the northern side are formed of clays and ferruginous sandstones; but it is yet to be shown that these are continuous with the Tertiary formations of Tabatinga. Similar clays and sandstones occur all through Central and Eastern Brazil and in the Argentine Republic, but they belong to many different ages; no one who has studied geology in Brazil will be likely, on mere lithological grounds, to unite formations a thousand miles apart. The clays of the Lower Amazons, then,

may be older or newer than those of the Marañon, and the Tertiary sea which left the shells at Pebas may or may not have been united with the ocean by a Lower Amazonian strait. Some facts in geographical distribution lead me to suppose that Guiana was then united to Central and Southern Brazil. In that case the Amazons may possibly have flowed westward into the Tertiary sea from some high land farther east.

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HIBERNATION OF THE LOWER VERTEBRATES.¹

BY AMOS W. BUTLER.

IN a recent article in *Science* (Vol. iv, No. 75, pp. 36-39) Dr. C. C. Abbott gave the results of his observations of the hibernation of some of the lower vertebrates.

I have for several years, as opportunity offered, noted my observations in this line, and while my experience in some respects has been similar to that of Dr. Abbott, I feel that the results I have obtained may be appreciated by others similarly interested.

The climate of New Jersey and Southern Indiana is much the same; this fact will lead us to expect somewhat similar results from our observations.

The common box tortoise, called also "land tortoise" and "terrapin," according to locality, hibernates regularly in Southern Indiana. It frequents the drier woodland, partially overgrown with underbrush. It enters the ground in the latter part of September or early in October to a depth not exceeding a foot, the average being from eight to ten inches.

A few years ago, in March, I was burning over a track of woodland on which were a number of brush piles; when the fire burned out I passed by where some of the brush piles had been and noticed that the ground appeared to have been torn up as though a charge from a shot gun had been fired into it. Examination, in several instances, revealed the fact that the work had been done by tortoises. The heat having penetrated to the depth of their winter quarters and aroused them from their winter's sleep, they now sought the surface and the cause of their sudden awakening.

The day being quite cool I placed them in a beaten road which